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NEW OBSERVATIONS OF THE RED LINE OF THE SKY AT NIGHT IN AFRICA

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32262

Summary: Observations of the red line of the night airglow have been simultaneously made in Tamanrasset (Algeria) and Agadez (Republic of Niger) from October 18th to November 3d, 1962. The altitude of the intertropical arc, deduced from trangulations, remained between 235 and 280 km. The structure of the arc has been investigated, together with its movement during the night. The correlation between the airglow phenomena and the structure of the atmospheric F layer has been more thoroughly considered than before. The recombination coefficient is very small in the F layer: the structure of this layer is controlled by the plasma movements.

I. INTRODUCTION

In a series of papers, it has been demonstrated that the behavior of the red line of oxygen at the Station of Tamanrasset is very different from the classical one as observed in the middle latitudes /1/; that, at this station, in the winter at least, an arc traverses the sky, vertically to the meridian, and that it is accompanied also by an emission of the line 5,577 /2/; that this arc is associated with another arc that is located symmetrically in respect to the true magnetic equator /3/. It has been shown, finally, /4/, that a formula suggested earlier /1/ made it possible to establish, in a highly satisfactory manner, a connection between the intensity of the red line and the parameters $_0F$ and h'F of the ionosphere layer F.

Observations made at other stations located at low latitudes contribute to the support of these findings /5/, /6/, /7/.

The two arcs formed by the line 6,300, and accessorily by the line 5,577, have been designated as the "intertropical arcs." The properties of the Northern arc have already been discussed rather throroughly on the basis of the observations made at Tamanrasset in January 1960 /2/ and in November of that year /3/; more particularly, indications were obtained regarding the movements of the arc and its altitude; we shall come back to these subjects when we shall discuss observations that have been made recently.

This new project entailed the installation, during the period of the new moon of the end of October and the beginning of November 1962, of two stations for observation, one at Tamanrasset (Algeria), latitude 22°47'N, longitude 5°32'E, altitude 1400 m , and another at Agadez (Republic of Nigeria), latitude 16°58'N, longitude 7°59'E, altitude 500 m. Each one of these stations was equipped with a rotary photometer covering the sky at a distance of 75° from the zenith through two pairs of filters (in each pair, one narrow filter and one wide filter), one of which isolated the line of 6,300 Å, while the other one isolated the line of 5,577 Å ([1]).

Another photometer had been installed on the Hurel-Dubois airplane of the National Geographic Institute, which had taken care of the transport of the equipment, both ways, to the two ground stations. Unfortunately, it was not possible to obtain useful observations by means of that instrument.

On the basis of observations being made permanently at the Observatory of Haute-Provence, it had been found that, in November 1960, the emission of the red line at that station was still largely comparable to what it was at the time of maximum solar activity, and that that emission had then decreased very rapidly and was not any longer far removed from what had been observed during the preceding period of minimum activity, even though it was still slightly larger. Under these conditions, we believed that it might be useful to examine the consequences of this weakening of the solar activity in the intertropical arc at Tamanrasset. The inclusion of the station of Agadez was justified by our wish to perform triangulations on the arc, and as a matter of fact, it turned out to be of great importance, since it was found that the arc, even though it was very

([1]) The observations pertaining to the line 5,577 constitute the topic of a separate paper by Mrs. Christophe-Glaume.

close to Tamanrasset at the beginning of the night, did not remain there throughout the night as it did in 1960, but that it moved rather rapidly toward the South and could then no longer be observed from Tamanrasset but solely from Agadez.

The ionospheric depth-finder of the University of Algiers which is located at Tamanrasset, was operating throughout the duration of our mission in excellent conditions and the ionograms were analyzed by the Ionospheric Research Team of the National Centre of Telecommunication Research (France). At the occasion of this work, the Team organized also a provisional sounding station at Agadez. Unfortunately, the portable depth-finder used produced tracings that were too weak for the high frequencies involved so that only the equivalent height of the layer F could be measured.

II. ALTITUDE OF THE NORTHERN INTERTROPICAL ARC.

The photometer used turns around the horizon at the constant distance from the zenith of 75°. When an arc traverses the sky, and when its peak is located at a distance from the zenith that is clearly less than this limit, then the photometer will meet the two "feet" of the arc in the course of one rotation. In that case, the recording will present two clearly distinct maxima, e.g., in Fig. 1 which shows various cycles that were obtained in the course of the night of 23 October 1962, at Tamanrasset as well as at Agadez, we find that two clearly separated maxima are present at Tamanrasset until 21:18 hours and at Agadez from 19:18 hours. When the arc is too low on the horizon for one of these stations, then the corresponding cycle will be characterized by the presence of one maximum only; that is the case at Tamanrasset from 21:18 hours on, at at Agadez at 13:14 hours.

When the arc entails the existence of two points on the recording, then the azimuth difference between these two points as counted from 0 to 360° by going through the North, will be called the opening of the arc and it will be designated

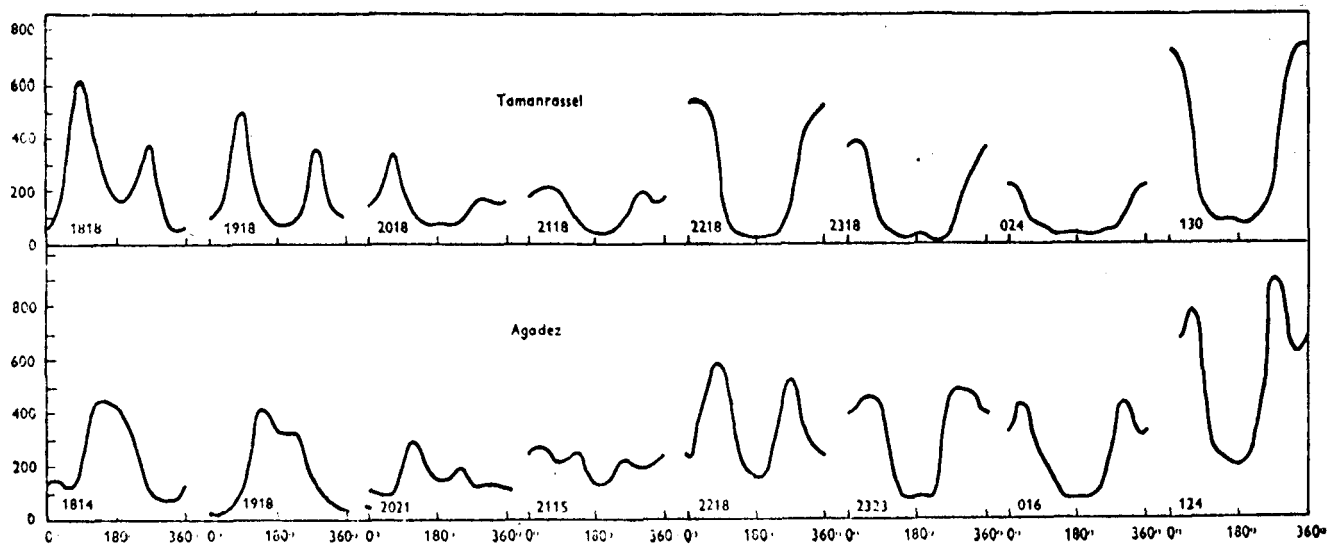

Fig. 1. Several cycles as observed at a zenith distance of 75°, at Tamanrasset and at Agadez, during the night of 23 October 1962. The hours, TU, of the observations have been indicated below each cycle.

by 2β. When Δ is the difference of the latitudes of the two stations that are being used for the triangulation, then we shall find /3/, with a generally sufficient approximation, that:

$$\Delta = \alpha(\cos \beta_A - \cos \beta_T),$$

where the indices A and T refer to Agadez and to Tamanrasset, respectively, and where α is the angular radius in degrees (function of the altitude h) of the circle as explored by the photometer at the distance from the zenith of ζ (75°) as given by:

$$\sin(\zeta - \alpha) = \frac{R}{R + h} \sin \zeta \qquad (R \text{ - radius of the earth}).$$

The possibility of triangulation between two stations is limited to those cases where the recordings obtained will show both of the points in good definition. During the last series of observations, the arc moved rapidly at the beginning of the night and triangulation was, as a matter of fact, possible only during a short period of time. The values which were obtained, have been shown in Table I. They have been combined with the values of the altitude h'_F of the base of the layer F, which are the result of the ionospheric soundings taken at

Tamanrasset and Agadez, as well as the values that had been obtained previously in November 1960, by triangulation between the station of Tamanrasset and an airborne station.

TABLE I

Altitudes of the arc

DATE	T. U.	h	h'_F TAM.	h'_F AGADEZ	DATE	T. U.	h	h'_F TAM.	h'_F AGAD
13-XI-60	20.45 à 22.18	260 ± 10	265-245		22-X-62	19.00	240	< 225	
						[illegible]	250	220	
						20.00	235	230	
14-XI-60	19.15 à 20.27	310 ± 10	250-225			20.30	265	240	
						21.00	285	235	
24-XI-60	23.00	240 ± 30	220		23-X-62	19.00	235	205	
	23.24	300 ± 30				19.30	255	215	
	23.36	340 ± 30				20.00	275	230	
	23.18 à 0.49	400 ± 30	350			20.30	275	245	<
21-X-62	19.30	260	200		25-X-62	22.00	245	245	
	20.00	280	215			23.00	240	215	
	20.30	250	225		26-X-62	19.30	245	235	

[Portion of table missing in photocopy]

The probable error affecting the 1962 altitudes amounts appreciably to 20 km. The values of h'_F as measured at Agadez and at Tamanrasset are generally different; But then the arc is located between these two stations; moreover, the comparison of h with h'_F of Tamanrasset - the only one that we are able to perform in regard to a considerable number of values - has an indicative value only. We obtained for the average $h - h'_F$ (TAM) the value of $\nearrow$ 32 km. This difference would have to be of the order of magnitude of the scale level (hauteur d'echelle) relative to the molecular oxygen, and that is indeed the case, but let us repeat once more that the scope of this conclusion is diminished by the fact that the ionospheric sounding has not been taken at the vertical of the arc itself.

It seems that one might even take recourse to a purely photometric triangulation, when the arc, at at least one of the stations, does not produce two distinct maxima on the recordings. Let us examine this possibility for the simple case of a flat ground (Fig. 2).

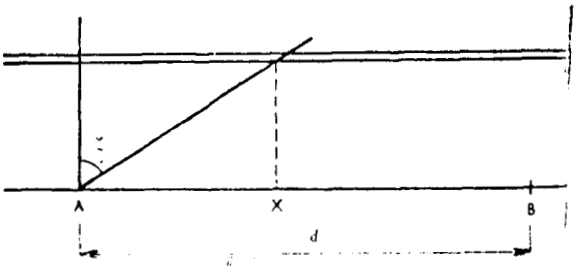

Fig. 2. Possibility of a photometric triangulation (case of a plane layer)

We shall measure, in A, the intensity at the distance from the zenith ζ, or I_A; the point aimed at is still projected [encore?] on the ground at the distance of h cotg ζ from A, and the zenithal intensity /intensite?/ that would be measured from X to the vertical of this point would be $I_A \cos \zeta$. In the same way, the measurement taken from B will be projected on the distance (d-h cotg ζ) of A and will correspond to the zenithal intensity of $I_B \cos \zeta$. Graphs of the variations of I cos ζ as a function of cotg ζ for one /illegible/ of — cotg ζ for the other one should be capable of superposition by means of a translation the value d/h of which would make it possible to determine the altitude.

Attempts made in that direction have led only to extremely disappointing results, and that is due to the fact that the indications of the two photometers will not remain completely identical (1), and also to the variations of the atmospheric transparency which is not so good at Agadez as it is at Tamanrasset (lower altitude), and which even was distinctly poor on the 28 and 29 October, due to sand winds.

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(1) When light gauges are used normally, they will make it possible to make sure of the preservation of the absolute calibration, but during this mission we believed that we should use the light gauge, in order to make the recording through four filters possible, through one of the filters, and the gauge, which had been built for such a use, supplied only readings that were a bit too weak to provide a truly effective control of the calibration; and this was especially so at Agadez, where the temperature was very high at times.

We have made use of the possibility of combining the observations made at the two stations to reduce, every night, the observations of Agadez to the scale of Tamanrasset by allowing that the radius of the zones observed at each station is $\alpha = 7^{\circ}.2$, which corresponds to an altitude of 275 km.

III. STRUCTURE AND MOVEMENT OF THE NORTHERN INTERTROPICAL ARC.

The arc is moving, generally, toward the South as the night progresses; this has already been stated earlier /2/, /3/. We have also called attention earlier to a very peculiar phenomenon that was baptized the "transfer of points" /transfert de pointes/, in accordance with its appearance on the recordings, and this provisional designation was chosen at the time so as not to prejudge its true nature. This phenomenon consists in the fact that the two points that represent the feet of the arc on a recording of one circuit of the horizon (or, at least one of these points) grow fainter, while at different azimuths, other points will appear and will become gradually more intensified. At the end of the process which lasts slightly more than one hour, the initial points have disappeared, and the new points have become substituted for the earlier ones.

In October and November 1962, some cases of transfers of points that may well be compared to the ones we have just described, were also observed, but in many of these cases, their modus of appearing was somewhat different, and that was undoubtedly due largely to the fact that the radiation of 6,300 Å was weaker than in 1960: in these cases, the arc used to disappear more or less completely and reappeared later a a different location. Fig. 3 shows the azimuths of the points of the arc as measured at Tamanrasset and at Agadez on 22 October 1962. A transfer of points took place, at the same time, at the two stations between 22 hours and 23:20 hours. An analagous transfer of points took place practically every night, and at more or less the same hour.

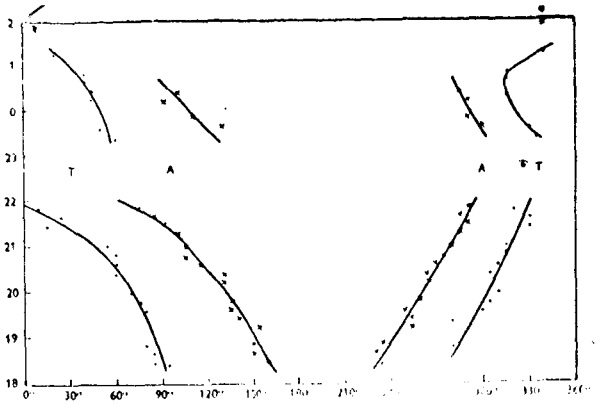

Fig. 3. Azimuths of the feet of the arc (measured at a zenith distance of 75°) at the two stations of Tamanrasset (T) and Agadez (A) on 22 October 1962. A point transfer took place between 22 hours and 23:20 hours.

When this effect was discovered, in 1960, the possibility was mentioned that it might be explained by the regular movement of just one arc alone, that possessed a multi-layer structure; in consequence of an effect of the perspective, it might have been possible that the layers could be seen separately as well as in projection, the ones above the others. The observations made on the aircraft /3/ were not favorable to that hypothesis, and the present observations which have included several observations of a transfer of points, that occurred simultaneously at both stations, show that we actually have to do with the substitution of one arc by another arc. We intend, for that reason, not to use the term "transfer of points" any longer to describe this phenomenon, which shall henceforth be called a "substitution of arc."

It is interesting to show for one and the same night, what is the variation of the intensity of the red line, as a function of the time, for different latitudes. We chose the night of 27 October which is quite representative (Fig. 4). We have determined the average of the intensities measure, in Rayleighs, for the pairs of points that are placed symmetrically in their relation to the meridian, i.e. for the points of azimuths 150 and 210, 120 and 240, 90 and 270, 60 and 300,

30 and 330. For an altitude of 275 km, these pairs of points will correspond, respectively, to the following latitudes:

For Tamanrasset . . . . 29°3 26°5 22°8 19°1 16°3

For Agadez . . . . . 23°5 20°7 17°0 13°3 10°5

In the figure, those of the observations made at Tamanrasset and Agadez have been regrouped, that refer clearly to the same latitude, and it is possible to see that the corresponding curves show a general form that is very similar.

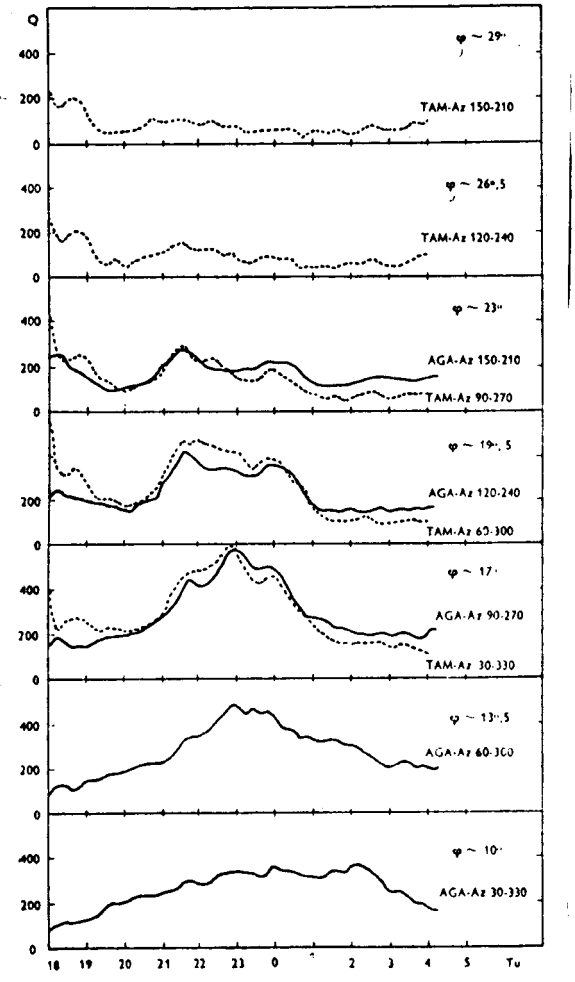

Fig. 4. Variations of the intensity of the red line 6,300 as functions of the time at various latitudes (φ) for the night of 27 October 1962.

The diurnal variation changes rapidly with the latitude, and that is due to the existence in the high atmosphere of a structure the extension of which is relatively inconsiderable as to the latitude (the intertropical arc), and

the intensity of which varies, and which changes its location as to the latitude.

The best way of describing the phenomena of the arc consists, without any doubt, in the utilization of a representation, which has been used frequently by F. E. Roach (see, e.g. /8/). It consists in presenting the intensities that have been observed along the meridian and which have been reduced to one vertical observation, as functions of the time. If the variations of the intensities that were observed, were simply due to a diurnal variation, or - to present the matter in another way - if the earth were turning under an invariable emitting layer, then the maps obtained for this occurrence would truly be maps of the layer. This is not strictly true, but we have already called repeatedly attention to the fact that the phenomena of the red line as observed in the East very frequently could be found again in the West, following intervals of time that correspond to those imposed by the rotation velocity of the earth /2/, /3/, in such a way that the curves represent, more or less, maps of the emitting layer.

Our photometer does not permit us any observation in the plane of the meridian; for that reason, we have been induced to use - as it has been stated above - the averages of measurements that were performed symmetrically in relation to the meridian. As a matter of fact, these are the curves of Fig. 4 and the analogous curves as established for the other nights that have been used to plot the graphs. The intensities have been divided by 2 so as to reduce them reasonably to represent zenithal intensities.

The curves of Fig. 5 demonstrate the following facts:

a) The arc has been subdivided into more or less isolated spots: the first one of these spots is, sometimes, at its maximum brightness at the beginning of the night, but this maximum may be delayed until 21:00 hours. Another spot passes through a maximum by 23:00 hours. Finally, the intensity of a third spot would

attain its maximum by 1:30 hours. All this is, by the way, slightly schematic. After 3 hours, and without any doubt ordinarily by 2:30 hours, the arc has disappeared completely.

b) The general form of the spots, and particularly their alignment, show that the intertropical arc moves toward the South, during the larger part of the night, and it is only just before its disappearance that it shows, perhaps, a tendency to climb again toward the North.

c) It occurs sometimes that the maximum intensity of the arc may be found at a geographic latitude of less than 10°, i.e. below the true magnetic equator. This is certainly the case for 25 October around 0:00 hours, and for the 27 October around 2:00 hours. Observations that would cover the region of the magnetic equator would present a certain interest for the exact determination of the behaviour of the Northern and Southern arcs upon their arrival in that region.

d) Toward the end of the period of observation, the arc becomes less clearly visible, but this is, without any doubt, a systematic lunar effect.

IV. AVERAGE VALUES DURING OCTOBER AND NOVEMBER, 1962.

Figs. 6 and 7 reproduce the horizon circuits as obtained on the basis of the average values of Tamanrasset and of Agadez. We shall be able to compare them with the analogous curves already published for Tamanrasset [2], [3]. They have been used to set up the Fig. 8 which shows the average variation of the azimuths of the bases of the arc (at a zenith distance of 75°).

Fig. 9 shows the average position, as to latitude, of the Northern intertropical arc for the three series of observations. We find that, in October 1962, the arc is located at a latitude that is lower, by an average of 5°, than in November 1960. This is certainly an effect of the phase in the solar cycle.

Fig. 10, finally, gives the diagram that is representative of the average intensity of the red line (in zenithal Rayleighs) for the series of observations

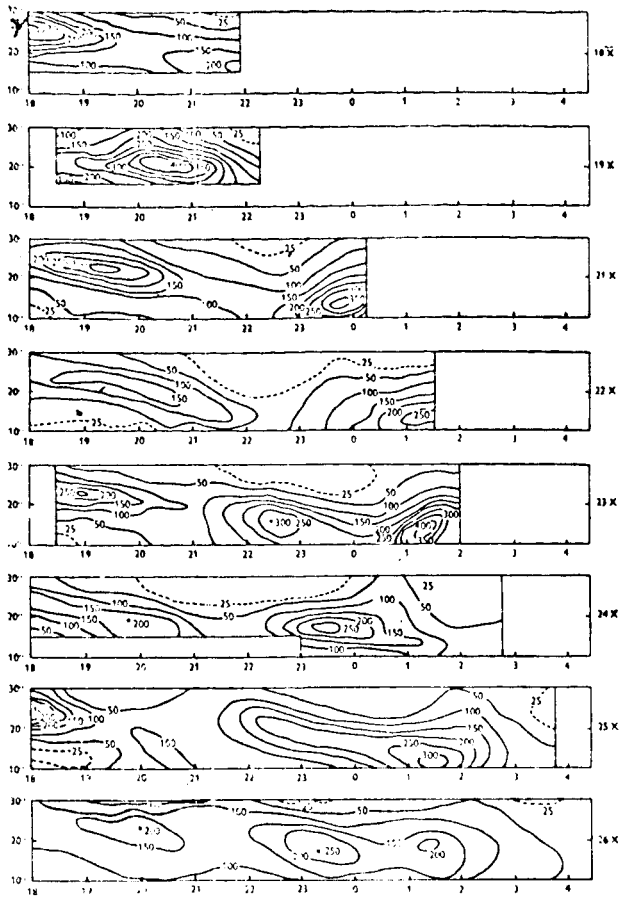

Fig. 5a. Curves of equal zenithal intensities, in Rayleighs, of the line 6,300 as functions of the geographic latitude and of the time (Tu). The true magnetic latitude (dip. latitude) will be obtained by taking away 10° from the geographic latitude. Those parts of the graphs, where the curves have not been indicated, are due to a lack of observations (moon, clouds, etc.).

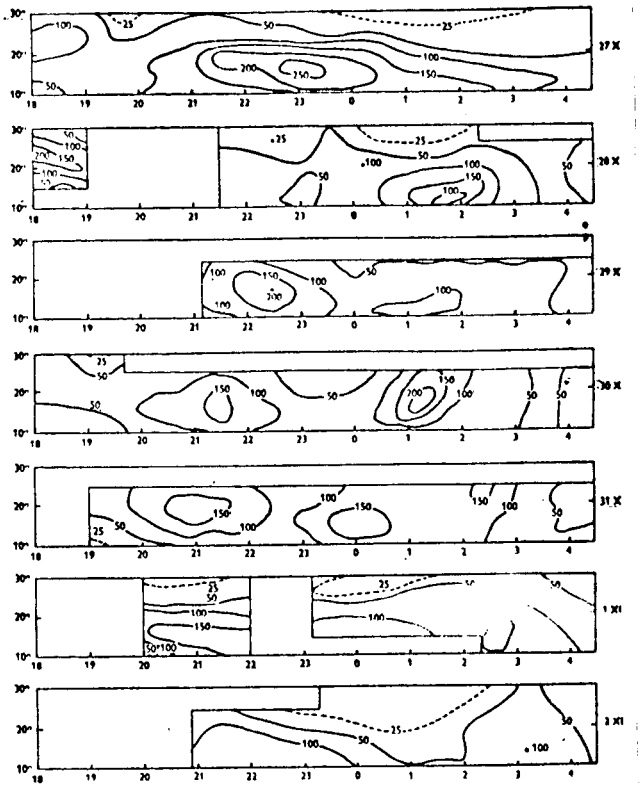

Fig. 5b. Continuation of Fig. 5a.

of October 1962 and of November 1960, as a function of the latitude and the hour. The intensities of 1962 are, as an average, three times weaker than the ones of 1960.

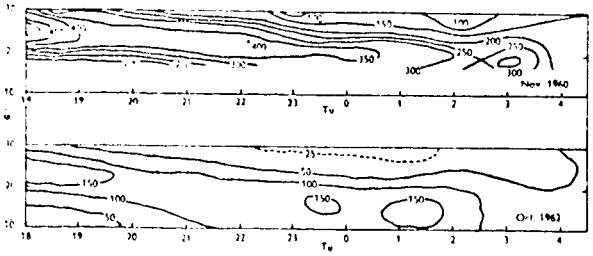

Fig. 10. Average intensity of the red line, expressed in zenithal Rayleighs, as a function of the latitude and of the hour, in November 1960 and October 1962.

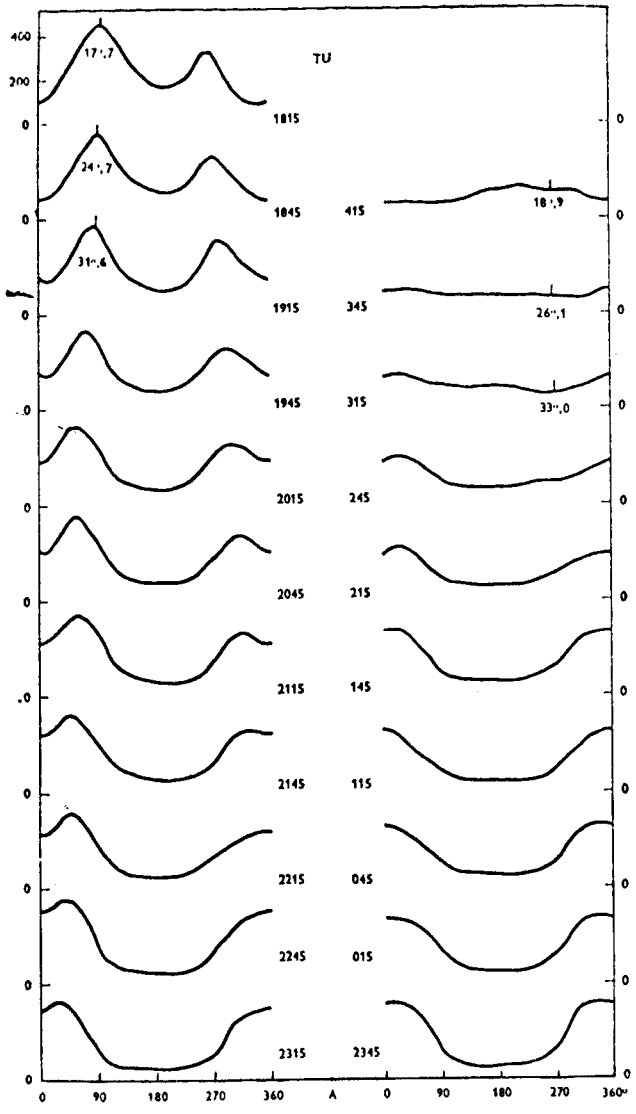

Fig. 6. Horizon circuits at Tamanrasset for the average of the observations. Intensity in Rayleighs. At the beginning and at the end of the night, the small marks indicate the azimuth of the sun, and the figures indicate its depression below the horizon.

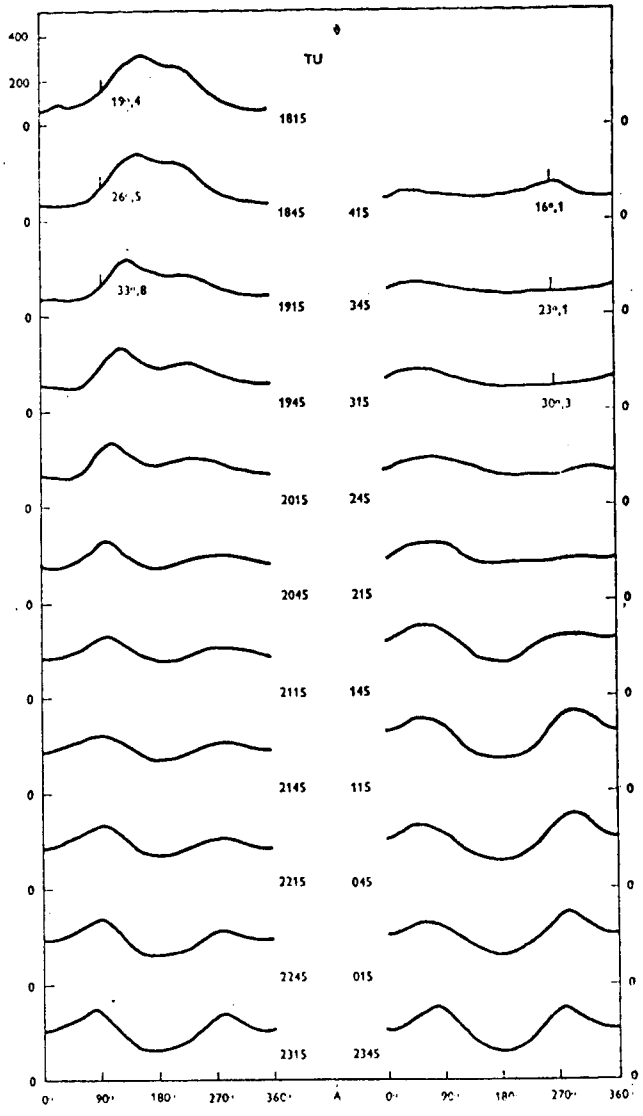

Fig. 7. Horizon circuits at Agadez. Same presentation as in Fig. 6.

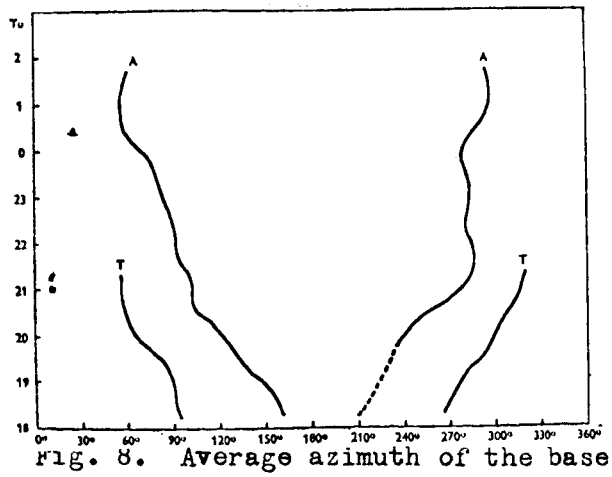

Fig. 8. Average azimuth of the bases of the arc at Tamanrasset (T) and at Agadez (A).

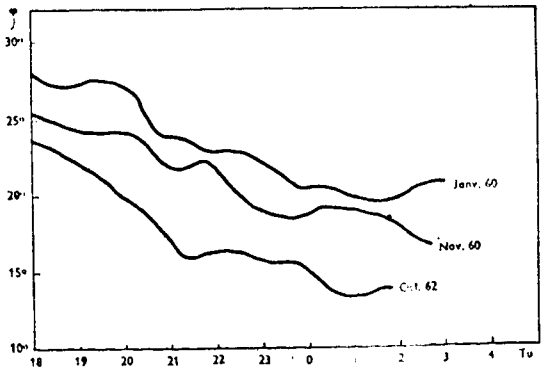

Fig. 9. Latitudinal position of the Northern intertropical arc for three differenct periods.

V. COMPARISON WITH THE IONOSPHERIC DATA. SEMI-EMPIRICAL FORMULAE.

In accordance with the mechanism suggested by Bates and Massey /9/ for the electronic recombination of the layer F, the intensity of the red line will have to be expressed by:

$$Q = k \int_{h'}^{\infty} nN \, dz,$$

when n and N are the densities of electrons and of oxygen molecules as a function of the altitude z, while h' is the virtual altitude of the layer F that is equal to the true altitude of its base during the hours of the night, and k is a proportionality coefficient.

When we assume that N decreases exponentially with the altitude according to a scale level H, then we shall find /4/, that Q may be written, in the first approximation, as:

$$Q = Kn(h' + H)\, e^{-\frac{h'-200}{H}}, \tag{1}$$

where K is a coefficient. But then, n is proportionate to the square of the frequency f_0. When we suppose further that it may be appropriate to add to Equation (1) a supposedly constant term C in the first approximation, so as to take into account an emission from the red line due to other phenomena, then we shall find that

$$Q = Kf_0^2 (h' + H)\, e^{-\frac{h'-200}{H}} + C \tag{2}$$

One has gone further in the simplification and, in order to take into account the fact that the data generally published for f_0 are not related to the altitude $h' + H$ but to the altitude of the maximum electronic density, i.e., to the critical frequencies f_0F, one had proposed the formula:

$$Q = Kf_0^2 F\, e^{-\frac{h'-200}{H}} + C. \tag{3}$$

The constants K and C do not have the same numerical values as in (2). This formula can be correct only when the quantity $f_0^2 (h' + H)$ is proportionate to $f_0^2 F$.

The zenithal intensity had not been measured in reality, and we have, therefore, used the average of the intensities at the zenith distance of 75° and at the azimuths of 90° and 270°, and this value was divided by 2.0 so as to reduce it to the zenith.

For the expression of Q in Rayleighs, Equation (3) has had the following results for Tamanrasset (October-November 1962), the only station where the ionospheric data can be used:

$$H = 44,4 \pm 3,9 \text{ km}$$
$$K = 3,78 \pm 0,14$$
$$C = 58,1 \pm 6,7$$

The values of the constants are not very different from those published in [4], and which related to the over-all observations made during the IGY-IGC, except that the new value of C is clearly smaller. As a matter of fact, the following had been found:

$$H = 41,3 \pm 2,5 \text{ km}$$
$$K = 2,94 \pm 0\,12$$
$$C = 109 \pm 4,2$$

Thanks to the courtesy of Miss Pillet, of the Ionospheric Research Team, it was possible to obtain measurements for f_0 at an altitude of $h' + H$, when H was assumed to be 45 km, in accordance with the above. In that way, we have obtained, in accordance with Equation (2):

$$H = 29,8 \pm 1,5 \text{ km}$$
$$K = 11,9 \pm 0,4$$
$$C = 53,4 \pm 5,8$$

The interesting point is the decrease of the scale level which has been reduced from 44.4 km to 29.8 km, while the precision of its determination has improved, at the same time.

Fig. 11 shows that the quantities $f_0^2 (h' + 45)$ and $f_0^2 F$ are not proportionate and, in consequence thereof, it is not surprising that a systematic error regarding the scale level H will result from this fact.

In short, Equation (5) makes it possible, as already pointed out previously to connect the photometric and ionospheric observations with one another, and

this is helpful, e.g., in predicting the behavior of the intertropical arcs in regions where they have not yet been observed, but it is the Equation (2) which will have to be used for the obtention of a more correct value of the scale level.

The series of November 1960, which was recorded with the same rotary photometer, provided the following results, after it had been handled in accordance with Equation (2):

$$H = 53{,}1 \pm 8{,}2 \text{ km}$$
$$K = 5{,}2 \pm 0{,}4$$
$$C = 17{,}1 \pm 13$$

The scale level was much larger in 1960 than in 1962. For that reason, the temperature of the high atmosphere in the layer F was probably higher in 1960, at a time that was still rather close to the maximum of solar activity, than in 1962.

When we convert these scale levels into temperatures, we shall find that:

$T = 520$ K in October-November 1962

$T \leq 920$ K in November 1960.

It must be understood that these are nighttime temperatures that are valid for an average altitude of the order of 270 km.

VI. COMPARISON WITH THE IONOSPHERIC DATA. UTILIZATION OF THE ELECTRONIC PROFILES.

The preceding methods of comparing the photometric and ionospheric data relating to layer F are not strict. It would be quite preferable to compare the light emission Q in Rayleighs at the zenith to the quantity:

$$2.10^{-6} \alpha \int_0^{\infty} n(e)\, N(O_2)\, dh ;$$

the factor of 2, which is perhaps slightly uncertain, has been introduced so as to take into account the fact that each recombination may lead to the emission of two photons of 6,300 Å. The factor 10^{-6} has been introduced to express the result of the calculation in Rayleighs; α, finally, represents the probability

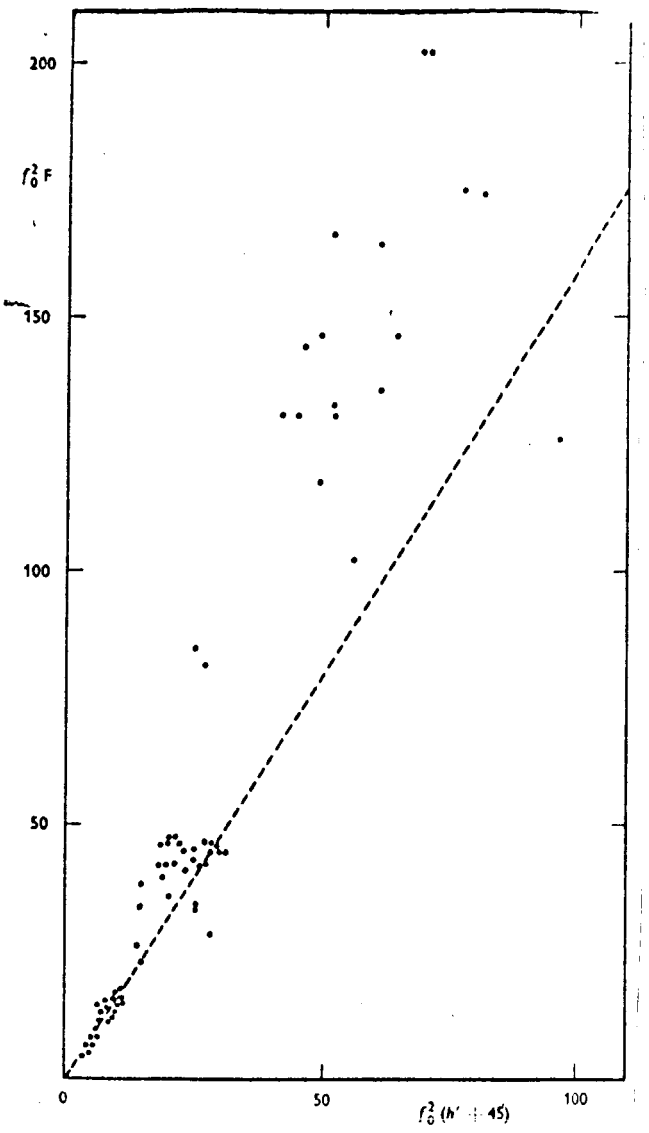

Fig. 11. Observations during October-November 1962. Relation between the measurements of f_0 at the altitude of hF + 45 km and of the critical frequency f_0F. The dotted straight line shows that the proportionality exists only near the origin.

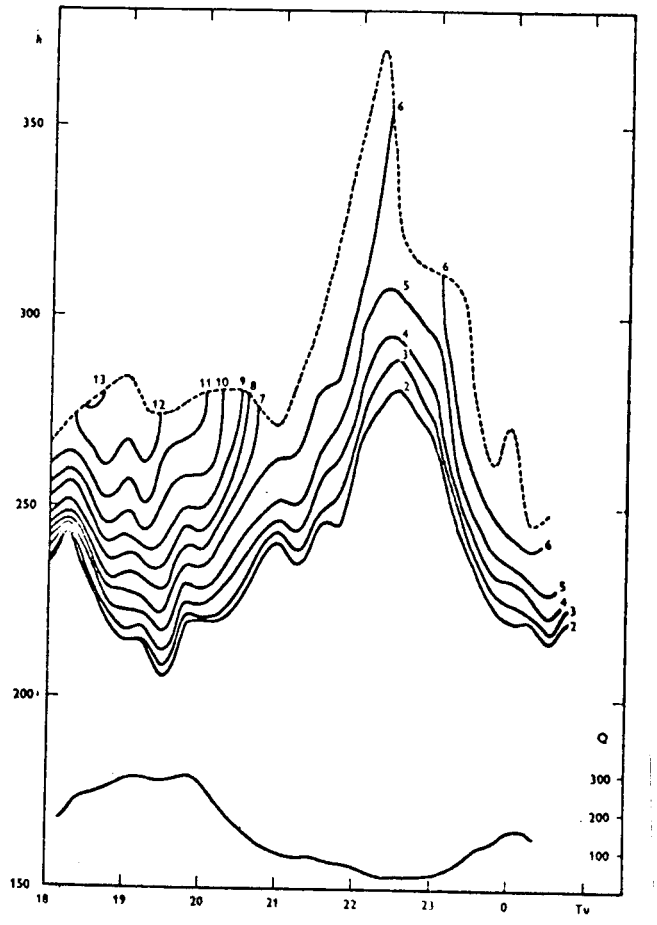

Fig. 12. Plasma frequency as a function of the altitude and of the Tu during the night of 21 October 1962 at Tamanrasset. The base of the layer F is practically indistinguishable from the curve $f = 2.0$. The dotted curve represents reasonably well the altitude of the maximum electronic density of the layer F. At the bottom of the Figure the zenithal intensity of the emission of 6,300 Å, in Rayleighs.

of the recombination. For the nights of 21 and 22 October 1962, Mr. C. Taier of the Ionospheric Research Team, has had the electronic profiles n(e) calculated for us, as function of h, at 15-minute intervals. Figures 12 and 13 show the

results of these calculations; the curves have been numbered by plasma frequencies as expressed in Mc ([1]). Let us remind ourselves that the latter ones are connected with the electronic density by the equation:

$$n = 1{,}22\ 10^4\ f^2.$$

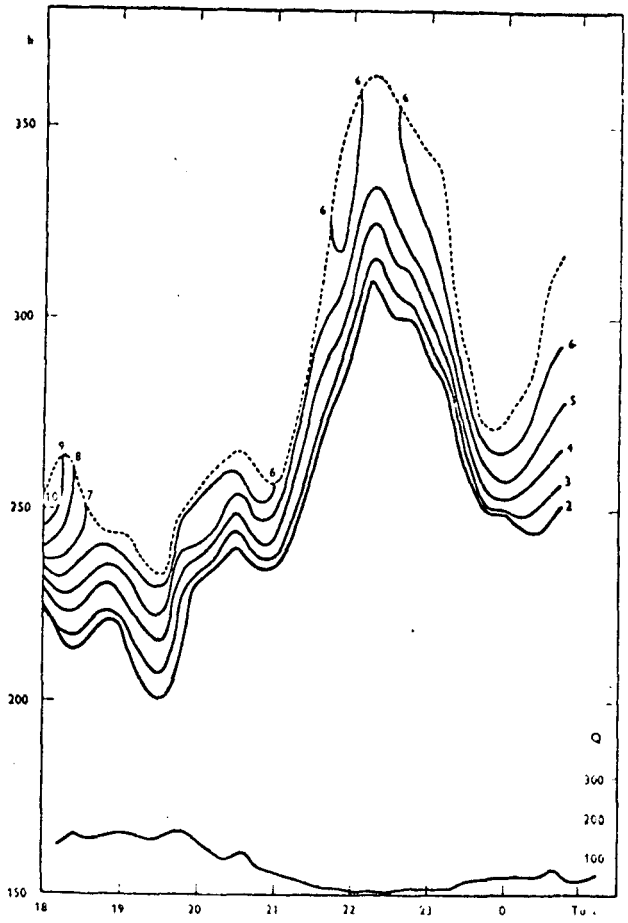

Fig. 13. Same arrangement as Fig. 12. Curves relating to the night of 22 October at Tamanrasset.

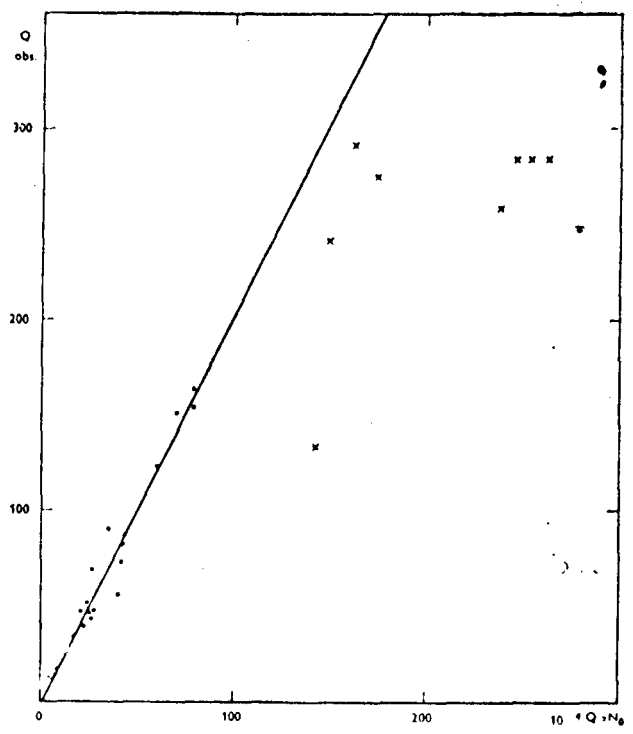

Fig. 14. Comparison between the densities observed and the intensities calculated (except for one factor) for the nights of 21 and 22 October 1962, at Tamanrasset. The crosses represent the observations until 20 hours TU, the ● represent the observations made after that hour.

Let us now assume that the density of the molecular oxygen may be expressed by

$$N(O_2) = N_0\, e^{-\frac{h-200}{H}},$$

([1]) The calculations were performed for values of f that were much closer together than the ones entered in Figures: 0.2 at the low frequencies up to 9.6 Mc, and then 0.4.

We shall then find that:

$$Q = 2.10^{-6} \alpha N_0 \int_0^{\infty} e^{-\frac{h-200}{H}} n(e)\, dh,$$

which we shall write - by way of leaving open the possibility of an emission due to another phenomenon - as follows:

$$Q = k_0 \int_0^{\infty} e^{-\frac{h-200}{H}} n(e)\, dh + C,$$

with:

$$k_0 = 2.10^{-6} \alpha N_0.$$

By making different assumptions regarding H - H = 20, 30, and 50 km - it will be possible to look for the relation between Q and the value of the integral ([1]) at the various times of the observations. Fig. 14 represents this relation for H = 26.6 km (we shall soon see the reason for this choice), which is rather analogous, as to its appearance, to the curves that have been plotted for the altitudes which we have just mentioned.

All points can be very well aligned on one straight line, with the exception of those of the beginning of the night (marked by crosses), up to 20 hours TU. We shall now disregard the latter points and calculate the sum of the squares of the remaining ones for each one of the values of H, viz., 20, 30, and 50 km; we shall also allow that this sum will vary, in a parabolic manner, as a function of H, and we shall find that it will reach a minimum exactly for H 26.6 km; it is, therefore, that value of the scale level which has been used for the preparation of Fig. 14.

([2]) /Should read: ([1]). Tr./ For these calculations, we shall allow that the electronic profile is symmetrical in relation to the altitude of the maximum electronic density. But, this classical and somewhat uncertain hypothesis cannot introduce a large error as to the value of the integrals, since the contribution of the altitudes that exceed the maximum, does not generally enter into the value of the integral itself for a fraction exceeding one fourth.

It would be important to explain why the results obtained before 20 hours TU cannot find a place on the straight line. The intensities of 6,300 as observed are then too weak, everything takes place as if, at the beginning of the night, a mechanism applied the brakes to the light emission; as a matter of fact, it rather appears as if none of the mechanisms that have been examined, would be able to account for an effect of such an importance.

We shall deduce from the angular coefficient of the straight line of Fig. 14 that $\alpha N_0 = 2.10^{-4}$. When we take, in accordance with M. Nicolet [14]

$$N_0 = 8.10^8,$$

as the density in oxygen molecules at an altitude of 200 km, then we shall find as to the coefficient of recombination per molecule that

$$\alpha = 2{,}5\ 10^{-13}.$$

The coefficient of recombination, viz., $\alpha N_0 e^{-\frac{h-200}{26,6}}$ has the values as reported in the Table and we shall compare with them the values obtained in accordance with the expression

$$10^{-4} e^{-\frac{h-300}{50}},$$

which was found by J. A. Ratcliffe, E. R. Schmerling, C.G.S.K. Setty, and J. O. Thomas [11] on the basis of an analysis of the ionospheric data by themselves.

h	200	250	300	350
$\alpha N_0 e^{-\frac{h-200}{26,6}}$	$2{,}00\ 10^{-4}$	$0{,}31\ 10^{-4}$	$0{,}046\ 10^{-4}$	$0{,}007\ 10^{-4}$
$10^{-4} e^{-\frac{h-300}{50}}$	$7{,}39\ 10^{-4}$	$2{,}72\ 10^{-4}$	$1{,}00\ 10^{-4}$	$0{,}37\ 10^{-4}$

The recombination coefficients that are the result of the observations of 6,300, are much smaller than the ones found by the authors cited; they could be doubted only if a new recombination mechanism were found that would not give rise to the emission of the line 6,300.

At each altitude, it is possible to calculate, on the basis of the electronic profiles, the quantity dn/dt, which supplies the chronological variation of the electronic density, and the quantity $\alpha N_0 e^{-\frac{h-200}{26,6}} n$ which represents the number of electrons that will disappear due to the recombination.

E.g., we shall find, for 21 October at 20:15 hours (on the basis of the profiles of 20:00 hours and 20:30 hours), that:

h	220	225	230	235	240	245	250	255	260	265	270	275	280
$-\frac{dn}{dt}$	54	119	113	164	226	277	308	325	356	337	312	279	291
Recombinations...	5	4	15	18	21	22	23	22	20	18	16	15	13

The number of the recombinations plays, therefore, only a negligible role in the ionic equilibrium of the layer F, at least in the tropical regions, and the essential phenomenon is the one of the movements of the ionised matter. This fact has been made tangible, by the way, in Figures 12 and 13: the periods of increase and decrease of the electronic density, on both sides of 22:30 hours, are reasonably symmetrical.

It is, therefore, quite evident that at a station such as Tamanrasset, the comings and goings of the ionised matter determine the main characteristics of the nighttime layer F. It is likely that the movements are due to the diffusion (governed by thermic effects) along the lines of force of the magnetic field.

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